V. Water Quality

A. Introduction

Samples were collected at the deepest section of the pond, and at each tributary and outlet for various chemical analyses as listed in Table V-1. The tributaries and pond outlets were sampled at least twice per month. Stream sampling was initiated in November, 1987 and continued through July, 1990. The pond was sampled at least once each month from July, 1987 through May, 1990. Raw chemistry data can be found in Appendix V-1.

Table V-1
Sampling Parameters for Mendums Pond Study

Parameter	Location
Temperature/Dissolved Oxygen	lake
pH	lake and streams
Acid Neutralizing Capacity	lake and streams
Specific Conductance	lake and streams
Chlorides	lake and streams
Sulfates	lake and streams
Color	lake and streams
Total Phosphorus	lake and streams
Nitrate Nitrogen	lake and streams
Total Kjeldahl Nitrogen	lake and streams
Turbidity	streams

B. Temperature and Dissolved Oxygen

Temperature is an important factor affecting water quality; an increase in temperature accelerates biological respiratory activities, decreases the solubility of dissolved oxygen in the lake, and has a marked effect on both the rate of adsorption of phosphorus and the equilibrium existing between sediment and interstitial water.

Mendums Pond portrays the typical stratification for north temperate lakes. By early August the surface layer was 20 degrees centigrade warmer than the bottom waters (Figure V-1). Mendums Pond had isothermal (uniform temperatures from top to bottom) conditions during spring and fall overturn, and was typically inversely stratified during periods of ice cover. Raw data and additional profiles are compiled in Appendix V-2.

The dissolved oxygen concentration in a lake is important to sustain all aquatic life. The depletion of oxygen in the bottom waters of a lake frequently occurs in the summer. This may have an effect on all other life in the lake, as it changes the redox potential, and allows phosphorus which is bound in the sediment to be released into the water. Fortunately, Mendums Pond does not experience this lack of oxygen in the bottom waters, so the sediments are not a potential source of nutrients to the pond. Phosphorus loading is discussed in Chapter VIII and sediment analyses are discussed in Chapter IX.

C. Phosphorus

Phosphorus is an essential nutrient for plant growth. In New Hampshire it is the limiting nutrient, which means that the amount of phosphorus in a lake determines the amount of algal growth in the lake. The presence of elevated concentrations of phosphorus (> 15 ug/L) will often accelerate the growth of algae and thus enhance the eutrophication process of lakes. A major focus of this study was to determine the sources of phosphorus before, during and after development of the western shore of Mendums Pond. Possible sources of phosphorus include precipitation, groundwater, surface runoff, septic leachate, tributary flux and internal phosphorus cycling.

1. Tributary Data

The mean total phosphorus values for each tributary are displayed in Figure V-3. The highest mean total phosphorus concentrations for the entire study period were observed at Bridge and Little Bridge Brooks (54 ug/L and 74 ug/L, respectively) and at McDaniel Brook (56 ug/L). The lowest mean concentration was observed at Little Powerline Brook (7 ug/L). The remainder of the tributary mean phosphorus concentrations ranged from 10 to 33 ug/L (Figure V-3). Figure V-2 shows the location of each sampling station.

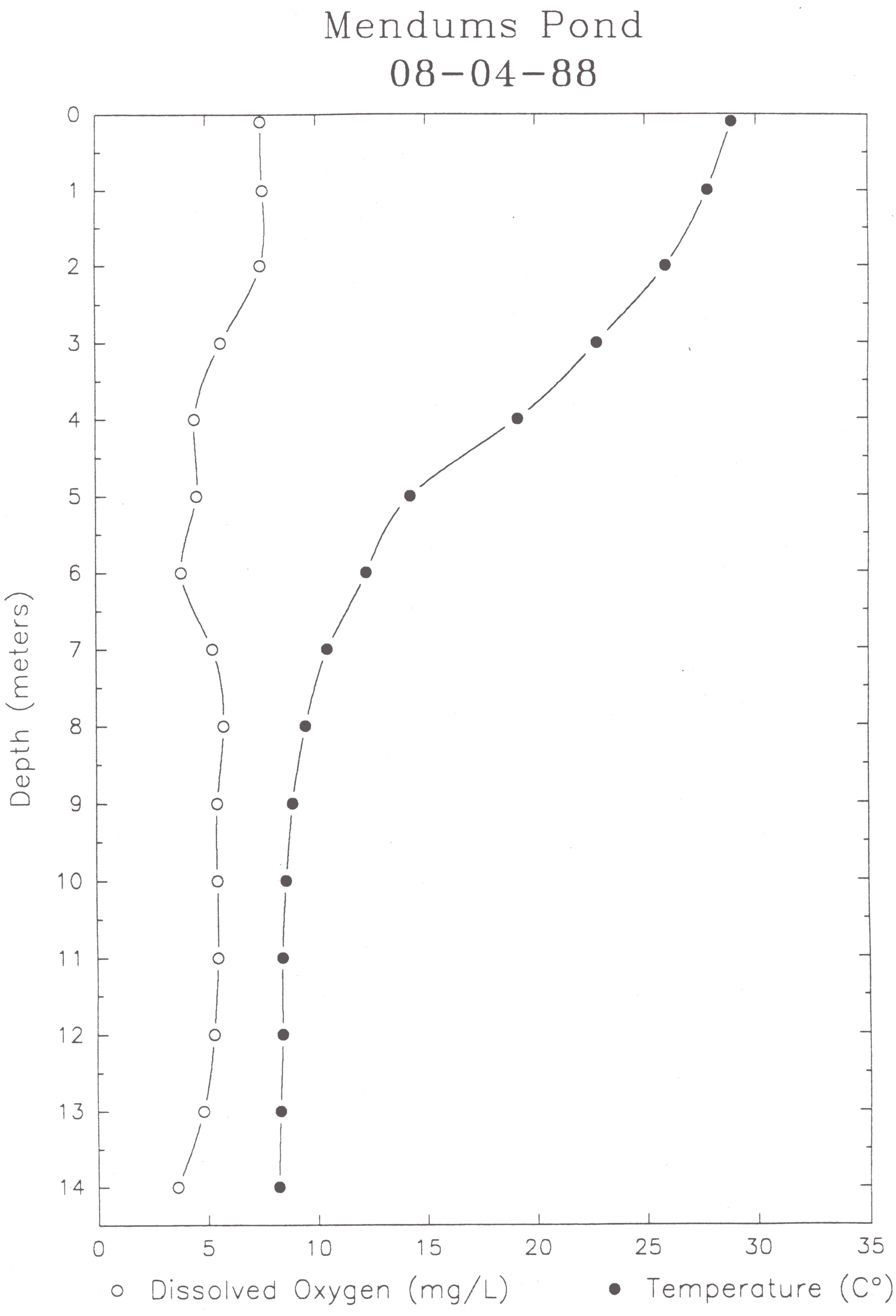

Figure V-1 Dissolved Oxygen/ Temperature Profile

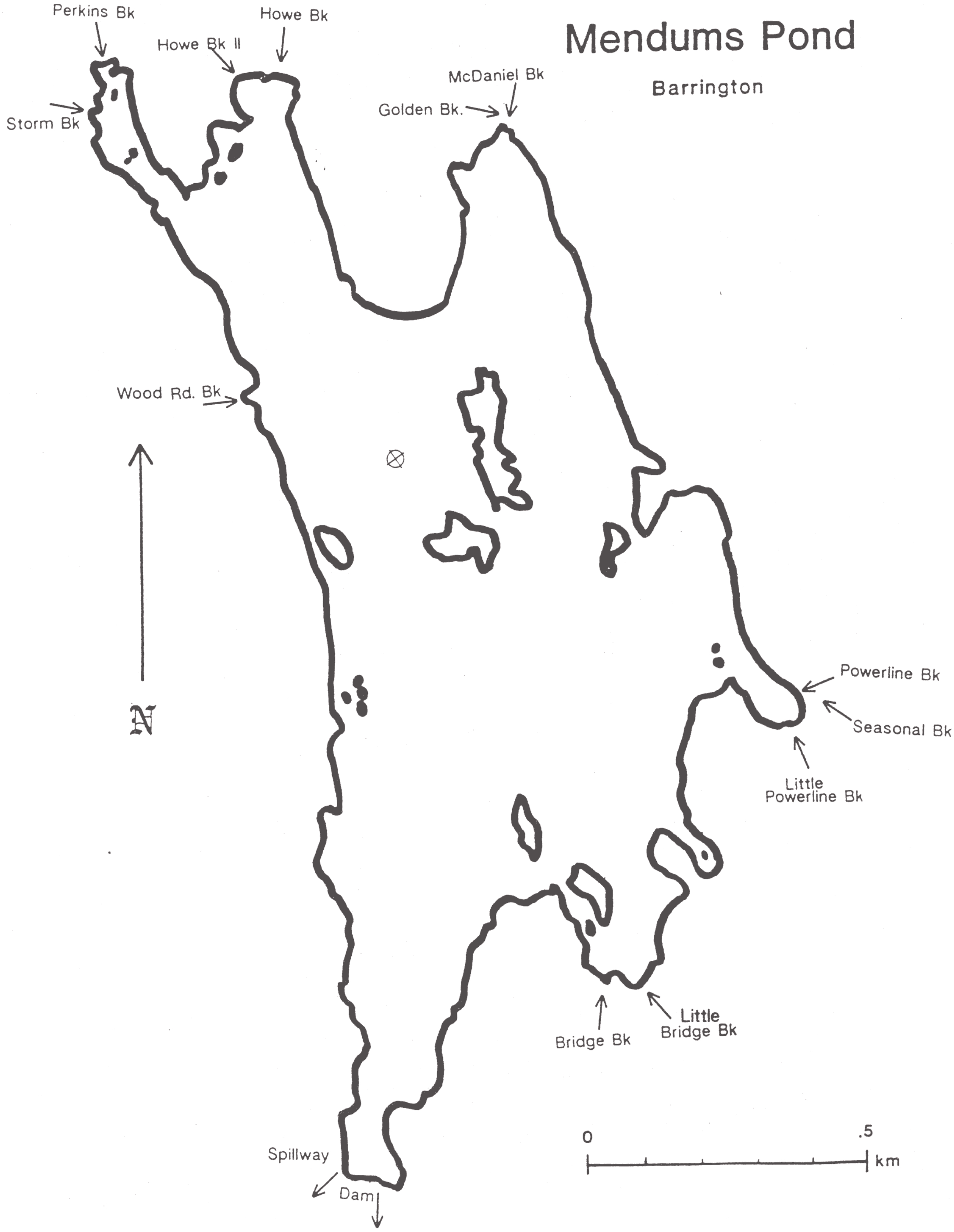

Figure V-2 Sampling Station Locations

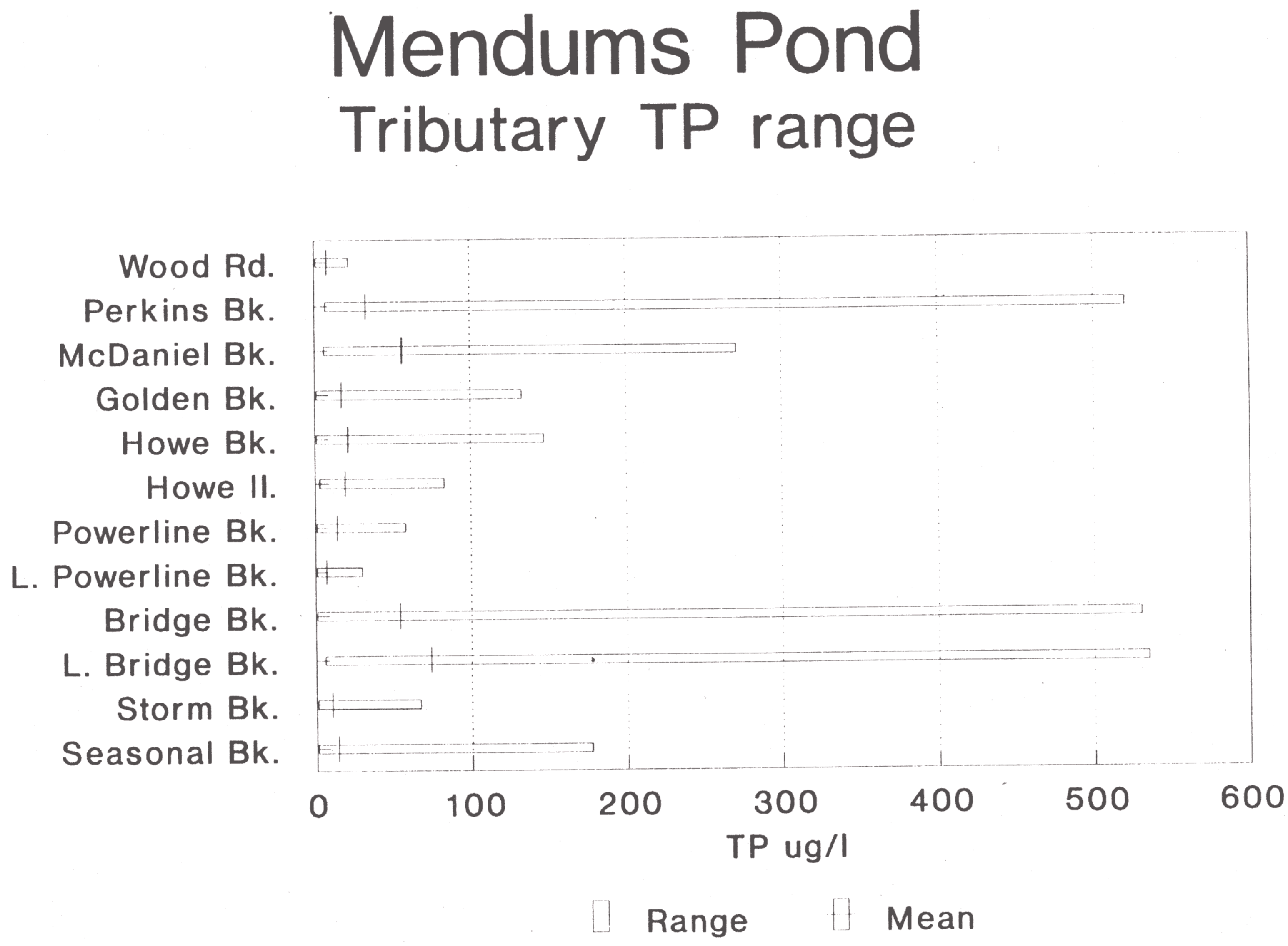

Figure V-3 Mean TP Values For Each Tributary

Seasonal tributary TP means are presented in Figure V-4. Most of the tributaries showed seasonal high values in the summer, as would be expected. The summer months show increased cultural activity (gardening, seasonal homes), as well as accelerated biological processes in the watershed. It should be noted that on July 16 of 1988 Barrington experienced a severe rain event which may have elevated the total phosphorus values. Increased surface runoff combined with soil disturbances from blow-down trees and wetland flushing all may have contributed to the elevated summer means. McDaniel Brook and both the Bridge Brooks showed the highest summer means as a result of upstream wetland flushing and severe wind disturbance in their subwatersheds.

One tributary, Seasonal Powerline, shows its highest seasonal mean TP concentration in the winter. However, this tributary was only sampled twice in this season due to low flow volumes. The elevated results may be due to both lack of sample points and the winter sampling technique which may have disturbed the sediment.

Overall, the tributary phosphorus values are not cause for concern (with the exception of aforementioned tributaries). No standard exists for tributary TP values for the State of New Hampshire, but in comparison with tributaries from other lakes studied the TP values for Mendums Pond are intermediate.

2. Lake Data

The total phosphorus concentration in the epilimnion of Mendums Pond ranged from below detection to 24 ug/L, with a mean total phosphorus concentration of 10 ug/L. The metalimnion and hypolimnion showed similar trends. This data is similar to the New Hampshire mean values of 11, 13 and 20 ug/L for the epilimnion, metalimnion, and hypolimnion, respectively.

Extensive total phosphorus data is available for Mendums Pond from 1987 through 1990. This data reflects valuable long term phosphorus trends in Mendums Pond. Mean annual phosphorus for each layer is presented in Table V-2.

Table V-2

Mean Annual Total Phosphorus (ug/L)

	1987	1988	1989	1990	Study Period
Epilimnion	10	7	14	15	10
Metalimnion	10	7	14	9	9
Hypolimnion	10	7	14	10	9

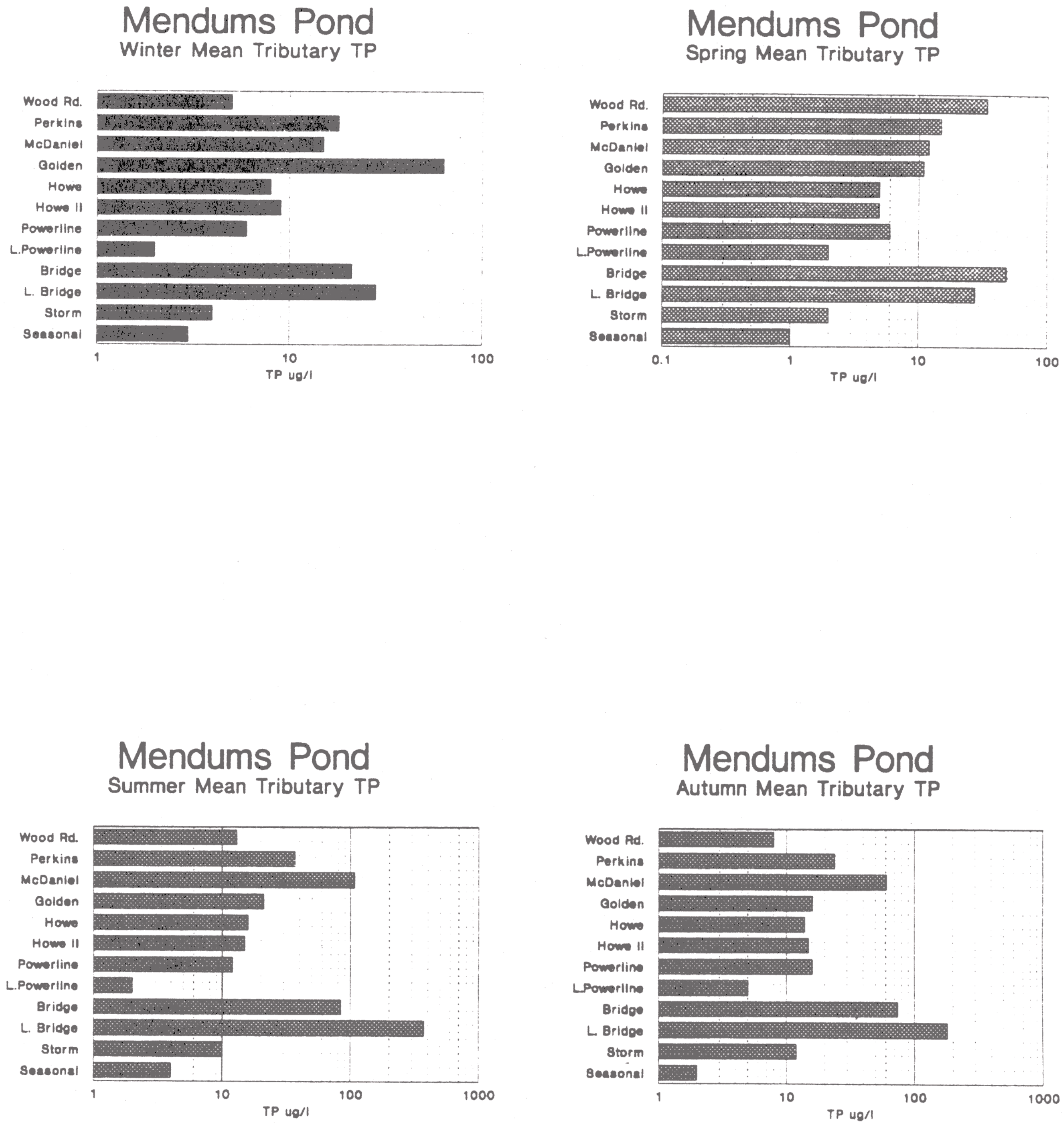

Figure V-4 Seasonal Tributary Tp (note: different scales)

Seasonal variation of TP in each of the lake layers is not pronounced. All of the layers show seasonal high values in the autumn. This is a season that is characterized by accumulation of phosphorus (the net result of the growing season) in the water layers until destratification occurs during fall "turn over". This coincides with a shift in phytoplankton dominance from greens to bluegreens. Bluegreen algae are opportunistic organisms and quickly utilized the available nutrients.

D. Nitrogen (Total Kjeldahl and Nitrate)

As a component of proteins, nitrogen is a major nutrient essential for plant growth and as such its quantities may affect a lakes productivity. It is not, however, the limiting nutrient in Mendums Pond. Nitrogen may be present in water as dissolved nitrogen gas, organic nitrogen compounds and inorganic nitrogen compounds including ammonia, nitrite and nitrate.

With the exception of some bluegreen algae that utilize atmospheric nitrogen (N_2) most algae use inorganic nitrogen. Of the forms listed ammonia is the preferred source because it is already at the reduction level of organic nitrogen and thus is assimilated into protein at a minimal energy cost. Ammonium-nitrogen is gradually oxidized by nutrifying bacteria into nitrite and nitrate.

Sources of nitrogen include precipitation, nitrogen fixation in the water and sediments by bacteria and certain bluegreen algae, and inputs from surface and groundwater drainage. Natural sources of the most commonly used form, ammonia, include excretory products from ammonifying bacteria, zooplankton and the urea of higher animals such as found in raw sewage.

Nitrite-nitrate nitrogen and total kjeldahl nitrogen (which includes all forms of Nitrogen both inorganic and inorganic) were the forms determined at Mendums Pond. The median value for lakes and ponds sampled in New Hampshire is 340 ug/L with a range of <100 ug/L to 1370 ug/L.

1. Tributary Data

a. Total Kjeldahl Nitrogen

Total Kjeldahl Nitrogen (TKN) mean values for each station are presented in Table V-3. All raw chemistry results are presented in appendix V-1. The greatest mean TKN values were observed in McDaniel Brook (580 ug/L) and Little Bridge Brook (680 ug/L). The high values may be attributed to the breakdown of detritus in the wetlands and beaver pond upstream from those particular stations. The lowest mean TKN values were measured in Little Powerline Brook (90 ug/L) and Seasonal Brook (80 ug/L). There is incomplete data for seasonal analysis.

Table V-3
Mean Tributary Total Kjeldahl Nitrogen
(ug/L) for Entire Study Period

Wood Road Brook	170	Powerline Brook	320
Perkins Brook	380	Little Powerline Brook	90
McDaniel Brook	580	Bridge Brook	390
Golden Brook	430	Little Bridge Brook	680
Howe Brook	310	Storm Brook	120
Howe Brook II	340	Seasonal Brook	80

b. Nitrate Nitrogen

Table V-4 presents median nitrate nitrogen concentrations for the study period. The results show little variation between stations. Most of the results were lower than the detection limit (50 ug/L). There is little seasonal variation between values for tributaries.

Table V-4
Median Annual Tributary Nitrate Nitrogen (ug/L)

Wood Road Brook	< 50	Powerline Brook	< 50
Perkins Brook	< 50	Little Powerline Brook	< 50
McDaniel Brook	< 50	Bridge Brook	60
Golden Brook	50	Little Bridge Brook	90
Howe Brook	< 50	Storm Brook	< 50
Howe Brook II	< 50	Seasonal Brook	< 50

2. Lake Data

a. Total Kjeldahl Nitrogen

Table V-5 presents mean Total Kjeldahl Nitrogen concentrations for each year in the study period. These values are similar to the state mean epilimnetic value (345 ug/L) discussed previously. The results for 1987 were slightly higher than successive years. This could be because the sampling program was initiated in July of that year, omitting winter and spring data. Winter and spring concentrations would typically be less, decreasing the annual mean.

Table V-5
Mean Annual In-lake Total Kjeldahl Nitrogen (ug/L)

	1987	1988	1989	1990	Study Period
Epilimnion	660	380	310	360	450
Metalimnion	500	350	320	300	390
Hypolimnion	290	320	310	300	300

b. Nitrate Nitrogen

The majority of data for in-lake nitrate nitrogen was below the detection limit (50 ug/L). The median concentrations for the study period were as follows: epilimnion, < 50 ug/L; metalimnion, < 50 ug/L; and hypolimnion, 60 ug/L.

E. pH and Acid Neutralizing Capacity (ANC)

pH, or the hydrogen ion concentration, is defined as the negative base 10 logarithm of the hydrogen ion activity in moles per liter. The pH scale ranges from 0 to 14 with 7 being a neutral value. 'Pure' water has a pH of seven which means it contains 1 X 10^{-7} moles per liter of hydrogen ions. The pH scale is logarithmic, therefore each unit change is a tenfold change. A pH of 5 is ten times more acidic than a pH of 6. "Natural" water at equilibrium with the atmosphere has a pH of 5.6. Most New Hampshire lakes are slightly acidic, with pH values between 7 and 6. When the pH value falls between 6 and

5.5 the waters are considered endangered, lakes with pH values from 5.4 to 5 are considered in the critical range, and below this point lakes are considered acidified.

One of the most important reactions occurring in water, and one which affects pH, is that of dissolved carbon dioxide; represented by the following equilibrium equation:

$$CO_2 + H_2O \rightleftharpoons H_2CO_3 \rightleftharpoons H^+ + HCO_3 \rightleftharpoons H^+ + CO_3$$

When phytoplankton consume CO_2 during daylight hours in photosynthesis, the equilibrium shifts toward the left. This results in fewer free H+ ions, causing a decrease in H+ ion concentration and thus an increase in pH. It is, therefore, not uncommon to find high (alkaline) pH values associated with an algal bloom.

The alkalinity of water is the capacity of water to accept protons, or, in other words, to neutralize hydrogen ions. It is primarily a measure of the concentration of carbonates, bicarbonates, and hydroxides in the water. New Hampshire's lake waters are generally low in alkalinity (ANC's range from 2 to 20 mg/L as $CaCO_3$). This is due in part to the states granite bedrock which contains few of these compounds. The result of this is that the lakes have a poor buffering capacity, and thus are more susceptible to some ionic pollutants than high alkalinity lakes.

The vegetation in a watershed also plays a role in the pH and ANC of a lake or pond. Wetlands, along with oak and pine forests, contribute to the low pH of drainage water in a watershed. This is evident in many of the tributaries to Mendums Pond which drain wetlands.

1. Tributary Data

Median tributary pH values for the study period ranged from 4.39 in Golden Brook to 5.64 in Storm Brook (Table V-6 Figure V-5). These numbers are low, and indicate a watershed sensitive to acidic inputs. Several of the low values may be due to wetlands drainage.

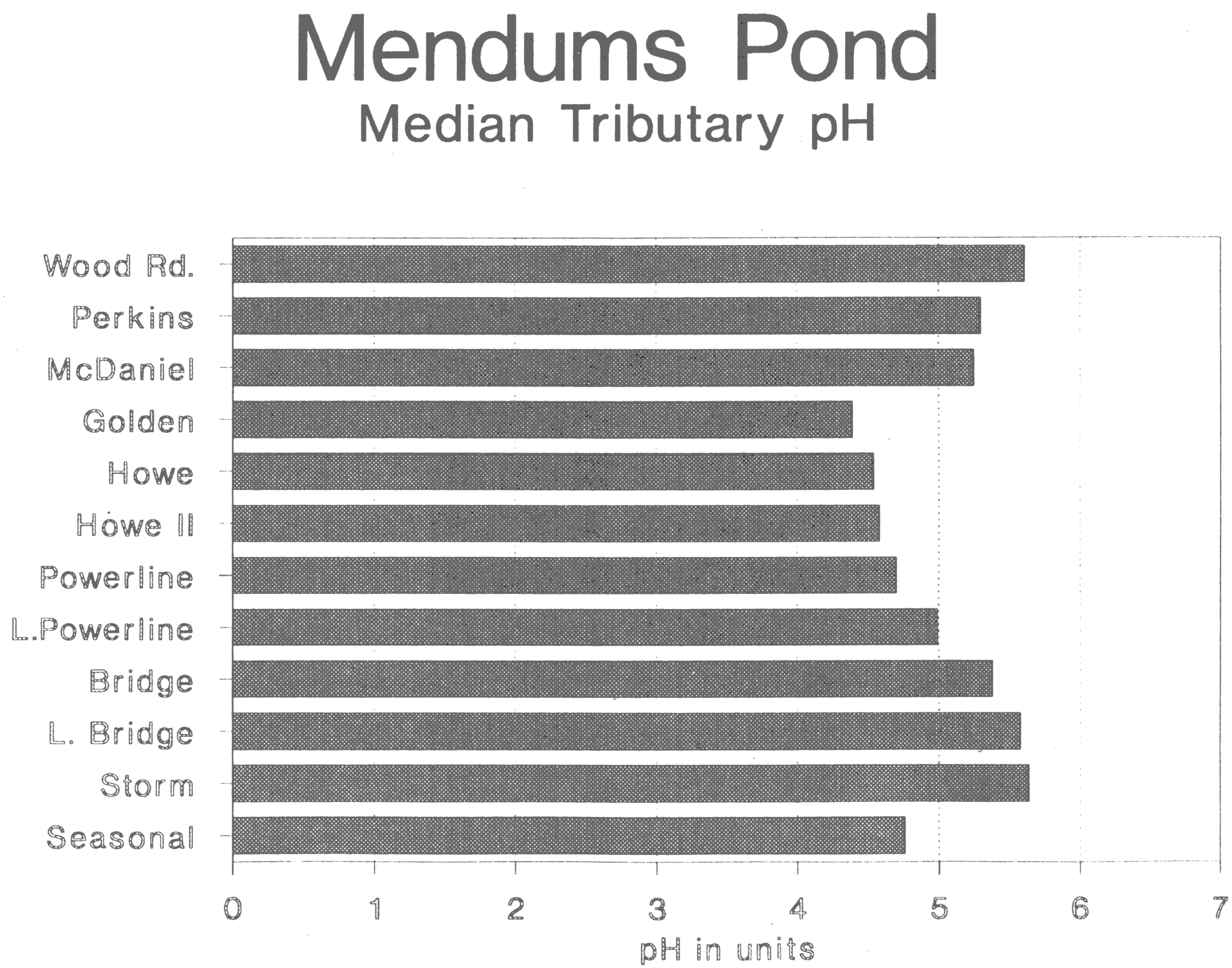

Figure V-5 Median Tributary pH Values

Table V-6

Median Tributary pH (units) and Mean A.N.C. (as $CaCO_3$)

for the 3-year Study Period

	pH	ANC		pH	ANC
Wood Road Brook	5.61	2.14	Powerline Brook	4.70	-0.64
Perkins Brook	5.30	0.96	Little Powerline Brook	4.99	-0.15
McDaniel Brook	5.25	1.18	Bridge Brook	5.38	1.86
Golden Brook	4.39	-2.08	Little Bridge Brook	5.58	3.40
Howe Brook	4.54	-1.28	Storm Brook	5.64	2.13
Howe Brook II	4.58	-1.00	Seasonal Brook	4.76	0.55

Mean tributary A.N.C. values for the study period ranged from -2.08 mg/L as $CaCO_3$ in Golden Brook to 3.40 mg/L as $CaCO_3$ in Little Bridge Brook (Table V-6). Mean tributary ANC values and sample ranges are graphically displayed in Figure V-6. See appendix V-1 for raw data. Tributary A.N.C. values are low compared to the NH State median and reflect little buffering capacity for additional acidic inputs.

Seasonal tributary pH and A.N.C. data is incomplete, lacking a summer sampling point. Overall trends show peak values for both pH and A.N.C. occurring in the autumn, and minima values in the spring. These trends may be due to the contributing effects of rainfall quantities (and their associated runoff capacity), snowmelt and the geology of the subwatersheds themselves. Seasonal tributary pH and A.N.C. data can be found in Table V-7.

2. Lake Data

Photosynthesis removes carbon dioxide from the lake which causes the pH to rise. For this reason, the photic zone tends to have higher pH values than the bottom layer, and the highest surface values occur during the summer when photosynthesis peaks. Surface and bottom values are usually similar during the spring and fall overturn periods. In general, Mendums Pond portrayed

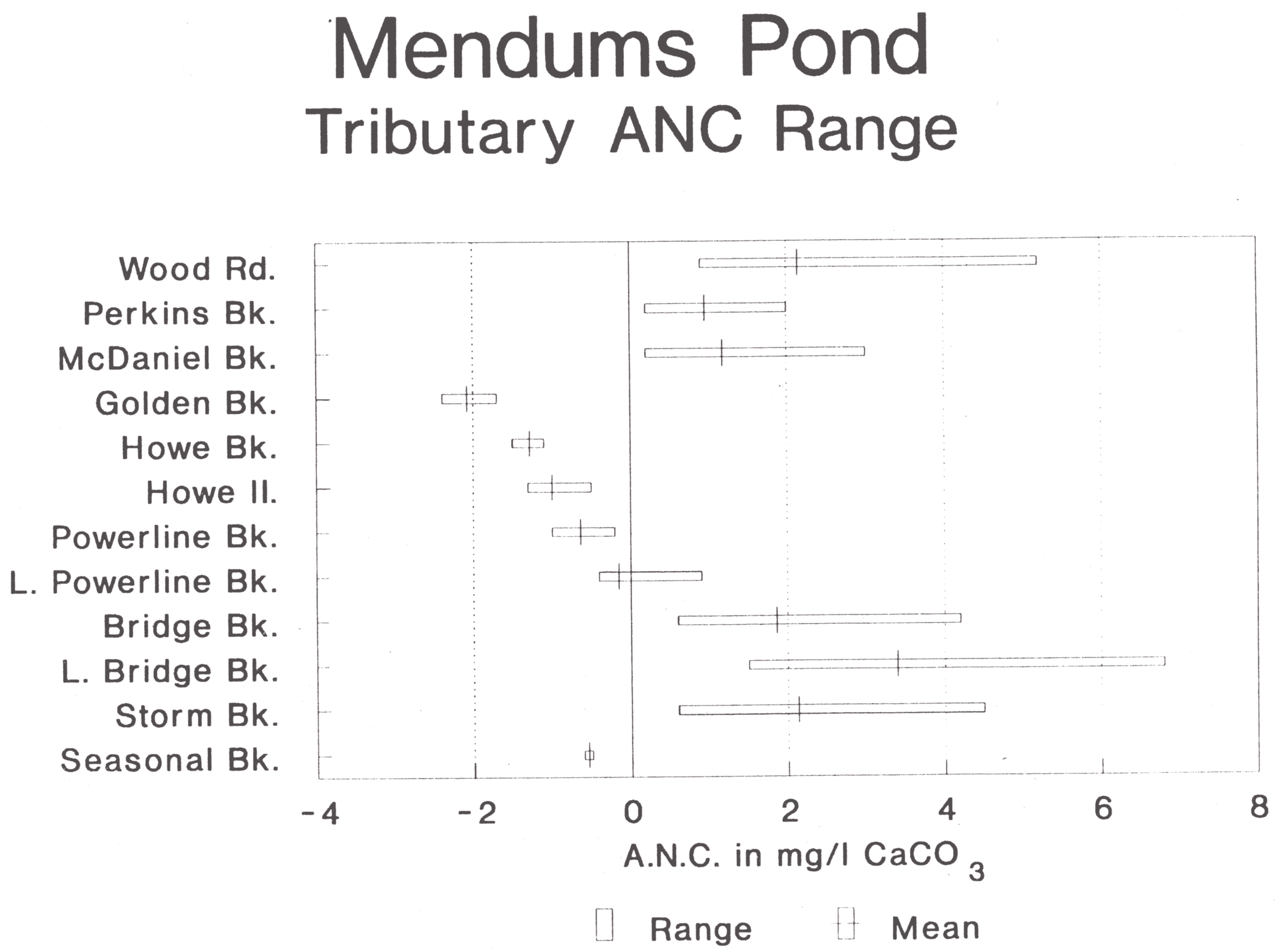

Figure V-6 Mean Tributary A.N.C. Values

Table V-7

Seasonal Tributary pH and ANC Values For Entire Study Period

	Winter		Spring		Fall	
Station	pH	ANC	pH	ANC	pH	ANC
Wood Road Brook	5.50	1.45	5.62	.90	5.83	3.45
Perkins Brook	5.22	.75	5.14	.20	5.47	1.55
McDaniel Brook	5.17	.75	5.13	.20	5.44	2.1
Golden Brook	4.37	-2.30	4.37	-.20	4.45	-1.7
Howe Brook	4.55	-1.30	4.50	-1.30	4.48	-1.3
Howe Brook II	4.63	-1.10	4.51	-1.30	4.59	-.5
Powerline Brook	4.68	-.75	4.70	-1.00	4.70	-.35
Little Powerline Brook	5.07	-.10	4.95	-.10	5.16	.90
Bridge Brook	5.42	1.55	5.37	.60	5.69	2.8
Little Bridge Brook	5.38	1.90	5.70	1.50	6.18	6.8
Storm Brook	5.73	1.30	5.53	.60	6.06	4.5
Seasonal Powerline Brook	4.76	-.60	4.77	-.50	4.74	---

these typical pH trends (Table V-8). The pH values of Mendums Pond were almost ten times lower than the median pH for New Hampshire lakes and ponds (6.50).

In contrast to pH, ANC values tend to be higher at the bottom of a lake. Higher A.N.C. values occur in the hypolimnion because buffering materials from the sediment are released to the overlying water. Seasonal ANC values for Mendums Pond are presented in Table V-9.

Table V-8
1987/88 Seasonal Median In-Lake pH

	winter	spring	summer	fall
Epilimnion	5.51	5.58	5.88	5.87
Metalimnion	5.60	5.64	5.72	5.77
Hypolimnion	5.49	5.60	5.60	5.69

Table V-9
1987/88 Seasonal Mean In-Lake Acid Neutralizing Capacity
(mg/L as $CaCO_3$)

	winter	spring	summer	fall
Epilimnion	0.8	0.9	---	1.4
Metalimnion	1.3	1.1	---	1.3
Hypolimnion	1.1	1.0	---	1.4

F. <u>Specific Conductance</u>

Specific conductance, or conductivity, is a measure of the ability of water to conduct an electrical current. This ability is determined primarily by the concentration of charged ionic particles present in the water. The soft water of New Hampshire generally has a low conductance relative to highly mineralized water found in some parts of the country. The conductance of water is related to the presence of dissolved solids and thus is usually higher in sewer effluents than in natural waters. The mean conductivity value for N.H. is 56.4 umhos/cm with a median of 38.0 umhos/cm.

1. Tributary Data

The lowest observed specific conductance value (19.67 umhos/cm) occurred in Perkins Brook. The highest value was observed in Storm Brook (66.50 umhos/cm). The means ranged from 23.50 umhos/cm to 58.91 umhos/cm. Means for each station are presented in Table V-10. These values, when compared to the New Hampshire means and medians are not outstanding or cause for concern. The conductivity values for each tributary did not vary much by season. The majority of the tributaries showed seasonal highs in the winter, possibly as a result of road salt runoff.

Table V-10
Mean Tributary Specific Conductance (umhos/cm)

Wood Road Brook	35.40	Powerline Brook	35.61
Perkins Brook	23.50	Little Powerline Brook	24.41
McDaniel Brook	25.79	Bridge Brook	38.17
Golden Brook	44.02	Little Bridge Brook	45.52
Howe Brook	34.89	Storm Brook	58.91
Howe Brook	32.47	Seasonal Brook	27.20

2. Lake Data

The mean conductivity values for Mendums Pond ranged from 25.02 to 25.90 umhos/cm in the water column. This data is considerably lower than the New Hampshire state mean, which is 56.40 umhos/cm. Table V-11 presents seasonal mean in-lake conductivity values.

Table V-11
Seasonal Mean In-lake Conductivity Values (umhos/cm)

	Winter	Spring	Summer	Autumn
Epilimnion	25.28	25.80	23.70	24.76
Metalimnion	30.10	23.85	24.18	24.85
Hypolimnion	25.05	23.95	24.53	25.55

G. Chloride and Sulfate

Chloride is one of the major anions found in water that naturally originates in several ways. These include the weathering of igneous and sedimentary rock, rainfall (occurring as cyclic chlorides), and many man-generated point and non-point sources such as road salt runoff and faulty septic systems. High concentrations of chlorides often indicate cultural pollution. The median chloride level for the lakes and ponds of New Hampshire is 6 mg/L.

1. Tributary Data

a. Chloride

Mean chloride concentrations ranged from 2.0 mg/L in Seasonal Brook to 13.8 mg/L in Storm Brook. Table V-12 presents the mean values for each tributary. Most of the values fall below the New Hampshire state mean. The higher results from Storm Brook may be due to road runoff. The sample station is just below a culvert under a steeply sloped dirt road and as such is subject to erosion. Seasonal distribution of chloride does not show marked changes, although most tributaries show slightly higher concentrations in the winter. This may be due to road salt runoff. Raw data is presented in Appendix V-1

Table V-12
Mean Tributary Chloride (mg/L)

Wood Road Brook	5.1	Powerline Brook	4.3
Perkins Brook	2.7	Little Powerline Brook	2.0
McDaniel Brook	2.7	Bridge Brook	5.8
Golden Brook	3.6	Little Bridge Brook	8.6
Howe Brook	3.2	Storm Brook	13.8
Howe Brook II	3.2	Seasonal Brook	2.0

The in-lake chloride results ranged from 1.0 mg/L to 3.0 mg/L and show no trends. Raw data is presented in Appendix V-1

b. Sulfate

Sulfates are utilized by all living organisms in one form or another, and are used in protein synthesis. Sulfates are usually abundant in aquatic ecosystems, entering through erosion of rocks, fertilizer runoff and through atmospheric transport by precipitation and dryfall. The mean sulfate concentration for New Hampshire lakes and ponds is 4 mg/L.

The tributaries showed the highest sulfate values in the winter, and the lowest in the fall. This may be due to utilization of sulfates by organisms in the fall and in the winter, with winter being lowest due to decreased metabolic activities and utilization.

Presented in Table V-13 are mean sulfate concentrations for each tributary to Mendums Pond. Mean sulfates ranged from 2 mg/L in Perkins Brook to 6.1 mg/L in Seasonal Brook. These values are typical for New Hampshire surface waters.

Table V-13
Mean Tributary Sulfate (mg/L)

Wood Road Brook	4.4	Powerline Brook	4.0
Perkins Brook	2.9	Little Powerline Brook	4.9
McDaniel Brook	3.1	Bridge Brook	3.5
Golden Brook	4.0	Little Bridge Brook	3.8
Howe Brook	3.2	Storm Brook	3.9
Howe Brook II	3.6	Seasonal Brook	6.1

2. Lake Data

The in-lake sulfate values ranged from 2.9 to 7.0 mg/L. The mean concentration for the epilimnion, metalimnion and hypolimnion was 3.0 mg/L, 3.8 mg/L and 3.5 mg/L respectively. Seasonal variation showed the highest values occurring during the fall. This is probably due to increased precipitation at this time.

H. Apparent Color

Apparent color is the visual determination of darkness of water. Color in water may result from substances in solution (iron, manganese and leachate from decaying organic matter) and suspended matter (plankton and silt). Tea colored waters (color values of greater than 40 units) such as those draining from wetlands are generally naturally colored from decaying organic matter. The median color value for New Hampshire lakes and ponds is 25 units.

1. Tributary Data

Mean apparent color in Mendums Pond's tributaries ranged from 6 units in Seasonal Brook to 241 units in Golden Brook (hence, it's name!). Table V-14 shows the mean values of each tributary for the study period. The higher values can be attributed to drainage of wetland areas. In addition, the watershed around the pond is highly forested, and the breakdown of plant matter is probably also a large contributor. This coincides with the seasonal highs of the color values occurring during the fall during increased decomposition.

Table V-14
Mean Tributary Color (cpu)

Wood Road Brook	34	Powerline Brook	85
Perkins Brook	115	Little Powerline Brook	28
McDaniel Brook	112	Bridge Brook	64
Golden Brook	241	Little Bridge Brook	66
Howe Brook	150	Storm Brook	15
Howe Brook II	138	Seasonal Brook	6

2. Lake Data

Mean in-lake color values were 40 cpu in the epilimnion, 43 cpu in the metalimnion, and 44 cpu in the hypolimnion. These values are typical of water described as tea-colored. The high color data along with the relatively low pH, indicates that wetland drainage plays a significant role in the chemistry of Mendums Pond.

I. <u>Tributary Turbidity</u>

Turbidity is caused by the presence of suspended materials in the water. Turbidities are often highest during a storm event due to elevated erosion from runoff. High tributary turbidities result in lake siltation and the introduction of phosphorus to the lake or pond.

Turbidity measurements are presented in Table V-15. The October 5th sample was collected during a rain event, thus these results are slightly higher in turbidity than the other sample dates presented. Samples from Bridge Brook and Little Bridge Brook were significantly higher on this date. This may be due to the flushing of organic matter suspended in the marshy beaver pond upstream from these brooks.

Table V-15
Tributary Turbidity (NTU)

	1/5/88	10/5/88	1/4/89
Wood Road Brook	0.20	0.72	0.17
Perkins Brook	0.50	0.95	0.30
McDaniel Brook	0.25	0.52	0.31
Golden Brook	0.40	0.45	0.41
Howe Brook	0.15	0.33	0.37
Howe Brook II	0.15	0.37	0.23
Powerline Brook	0.45	0.63	0.89
Little Powerline Brook	0.15	0.23	0.43
Bridge Brook	0.40	2.40	0.92
Little Bridge Brook	0.40	4.10	---
Storm Brook	---	0.98	0.22
Seasonal Brook	---	---	0.62

New Hampshire Surface Water Quality Regulations (1990) state that Class A waters shall contain no turbidity unless naturally occurring. Class B and C waters shall not exceed naturally occurring conditions by 10 NTU's. Mendums Pond is a Class B waterbody, and the turbidity conditions sampled here are within the legal limits.